QR 4

March 1967

☿ ☾ ♀ ♄ ⊕
♇ ♂ ♆ ♃ ⛢

PLANETARY QUARANTINE

SANDIA LABORATORIES QUARTERLY REPORT - PLANETARY QUARANTINE PROGRAM

Planetary Quarantine Department 2570

SANDIA CORPORATION

PRIME CONTRACTOR TO THE U.S. ATOMIC ENERGY COMMISSION | ALBUQUERQUE, NEW MEXICO; LIVERMORE, CALIFORNIA; TONOPAH, NEVADA

Issued by Sandia Corporation,
a prime contractor to the
United States Atomic Energy Commission

Sandia Laboratories Quarterly Report - Planetary Quarantine Program

Fourth Quarterly Report of Progress

for

Period Ending March 31, 1967

Planetary Quarantine Department

Sandia Laboratory, Albuquerque, New Mexico

March 1967

Project Nos. 340.229.00
340.229.01
340.352.00

Work reported herein performed under NASA Contract Numbers R-09-019-040, H-13245A and W-12324.

TABLE OF CONTENTS

I - SYSTEMS STUDIES ACTIVITIES

(A) Program Development and Analysis

Two documents that deal with the subject of program development and analysis are being prepared. The first of these presents a framework in which objectives may be analyzed, and then presents an analysis of planetary quarantine objectives within this framework. The second document presents a scheme for developing an operational program from "primary" objectives of a nonoperational character. This scheme is then used to begin to develop an operational program from planetary quarantine (and other national) objectives.

1. Planetary Quarantine Objectives. Objectives may vary considerably in their degree of specificness. The major points of the document are:

   (a) if one wishes to formulate specific objectives, he should have an adequate amount of information about the means of attaining the objectives in order to insure that they can be achieved, and to insure that the cost of attainment is acceptable,

   (b) planetary quarantine research and development activities are just beginning to provide this type of information in a cost/effectiveness tradeoff format,

   (c) if the person(s) formulating objectives and the person(s) responsible for their attainment have different views, constraints or objectives in closely related areas, the formulation of specific objectives can create problems for the person(s) responsible for objective attainment, and

   (d) COSPAR and the United States, as "formulator" and "attainer" in this context, potentially have this problem.

2. Development and Analysis. Given program objectives of a nonspecific character, it is possible under certain conditions to develop a program leading to a collection of parameters which have the properties:

a) they may be measured or controlled (the latter either physically or a decision may be made about their magnitude).

b) after measuring those parameters for which measurement is appropriate, one may determine the feasibility of different specific program objectives. Furthermore, the cost of attainment of specific objectives may be obtained if cost data is available for the controllable parameters.

The document in preparation describes how such a program may be developed, and presents part of the planetary quarantine program developed in such a format.

(B) Requirements Modeling

To undertake the development and analysis described above, it is desirable to relate the parameters associated with the "primary" objectives to parameters which are somewhat more operationally oriented.

A model intended for this purpose has been developed which assumes that the prime objective of the lander phase of the Martian Exploration Program is that it be "successful". This, in turn, is expressed in terms of mission success and noncontamination of Mars within a time and cost constraint system. Since there is no absolute yardstick to measure the accomplishment of these ends, their attainment must be modeled in some way. The model attempts to translate the prime objective, and the subobjectives in terms of probabilities. Thus, the expression, "N lander missions are successful" is taken to mean with probability of at least $\hat{P}_{E.S.}$; the expression, "the planet Mars is not contaminated" is also taken to mean with probability of at least $\hat{P}_{N.C.}$. Finally, the expression, the lander phase of the Martian Exploration Program is "successful" must also be translated in terms of a probability $\hat{P}$. This latter minimum acceptable probability of the "success" of the program will in all likelihood be a policy decision. The aim of this model is to give a way of measuring this joint probability of success, i.e., the probability of successfully completing at least N missions and not contaminating Mars.

The first subobjective - N successful missions with minimum acceptable probability of at least $\hat{P}_{E.S.}$ - is expressed as:

$$P_{E.S.}(N,M) = \sum_{J=0}^{M} \binom{N+J-1}{J} P_S^N (1-P_S)^J \geq \hat{P}_{E.S.} \qquad (1)$$

where P_S is the probability of the "success" of an individual mission and M represents the number of additional missions that one must be prepared to launch in order to achieve the subobjective. That is, given $\hat{P}_{E.S.}$, P_S and N, the minimum M for which inequality (1) is satisfied may be found.

Assuming that cost is an important factor in determining an acceptable level of "success", and assuming that mission cost is not negligible, the model assumes the existence of an upper bound, $\hat{M}$, for M, i.e.,

$$M \leq \hat{M}.$$

In this case, if $\hat{P}_{E.S.}$, P_S, N, and $\hat{M}$ are given, then either there will be at least one $M \leq \hat{M}$ so that the inequality is true or M must be greater than $\hat{M}$ to satisfy inequality (1). In the latter case, this means that the objective of N successful missions with probability not less than $\hat{P}_{E.S.}$ cannot be met, and either N or $\hat{M}$ or P_S or $\hat{P}_{E.S.}$ must be changed. In the case where there is more than one $M \leq \hat{M}$ someone must decide which value of M to choose.

Once this particular value of M is chosen, one investigates the probability of contaminating the planet Mars, which depends on:

1. the probability, P_L, that a single lander contaminates the planet, and
2. the probability, $P_F(J)$, that the Jth extra mission is flown, $(J=0,\ldots,M)$.

Thus, the second subobjective of the program, that the probability of not contaminating Mars, $P_{N.C.}(N,M)$, be at least $\hat{P}_{N.C.}$ can be expressed as:

$$P_{N.C.}(N,M) = \sum_{J=0}^{M} (1-P_L)^{N+J} P_F(J) = \hat{P}_{N.C.} \tag{2}$$

The measure of program success, P, is now the joint probability of achieving the two subobjectives and can be expressed as:

$$P = P_{N.C.}(N,M) \cdot P_{E.S.}(N,M) \; . \tag{3}$$

P, as the measure of program success under the various operating constraints is now compared to $\hat{P}$. If $P \geq \hat{P}$, then the model states (for the given parameter values) that the lander phase of the Martian Exploration Program will be successful with probability P. If, however, $P < \hat{P}$, then the lander phase of the Martian Exploration Program does not meet the minimum acceptable probability of program success. In this case, a decision must be made either to change program parameters to make $P \geq \hat{P}$ or to reduce the value of $\hat{P}$ so that $P \geq \hat{P}$. This model, used as a planning tool, hopefully will afford a rational basis for such decisions.

Finally, a computation scheme has been prepared to investigate sensitivities among the parameters. In making such computations, $P_F(J)$ was assumed to be of the form

$$P_F(J) = \frac{\binom{N+J-1}{J} P_S^N (1-P_S)^J}{P_{E.S.}(N,M)}$$

Of course, $\sum_{J=0}^{M} P_F(J) = 1$. Intuitively, this choice corresponds to assuming that the ratio

$$\frac{(\text{Probability of launching exactly J additional missions})}{(\text{Probability of launching exactly M additional missions})}$$

is the same as the ratio

$$\frac{(\text{Probability of the Nth "successful" mission occurring on the (N+J)th launch})}{(\text{Probability of the Nth "successful" mission occurring on the (N+M)th launch})}$$

A report on this work is being prepared.

(C) Sterilization Models

Research is continuing on the model discussed in the previous quarterly report. Although this model may be of theoretical interest, inherent difficulties in application have prompted an attempt to introduce rationality by a simpler approach.

Consider a microorganism as a device of N vital systems such that inactivation results from the failure of any one of the N systems. Suppose also that the ith system, $i = 1,2,\ldots N$, is provided with a redundancy of n_i. Then from reliability theory, the probability of the device being functional at time t is given by

$$p(t) = \prod_{i=1}^{N} \{1-[1-q_i(t)]^{n_i}\} \tag{1}$$

where $q_i(t)$ is the probability that a system of the ith type is functional at time t.

Translating from devices to spores and from N systems to N types of vital molecules with n_i being the number of molecules of the ith type, p(t) of equation 1 is probability of spore survival to time t with $q_i(t)$ being the probability that a molecule of the ith type has not been inactivated at time t.

Assume that $q_i(t)$ is given by the expected number of molecules still active at t divided by initial concentration. Thus

$$q_i(t) = c_i(t)/c_i(0) \tag{2}$$

where $c_i(\cdot)$ is the concentration.

If the deactivating reaction is 1st order,

$$q_i(t) = \exp[-kt]$$

and if it is 2nd order,

$$q_i(t) = 1/[1+c_i(0)kt]$$

where k is the reaction rate constant.

Figure 1 shows typical curves for various reactions and assumptions regarding N and n_i. It is of interest that actual spore survival data (in a dry heat thermal environment) exists in each of these forms.

Figure 2 shows comparisons to Silverman's data for $N = 1$, $n_i = 2$, and deactivation by first order kinetics. Rate constants of .55 $hr.^{-1}$ at $106^{o}C$ and 2.65 $hr.^{-1}$ at $120^{o}C$ were obtained experimentally. Thus, in effect, this data at $106^{o}C$ and $120^{o}C$ has been "fit" by varying the reaction rate parameter. The Arrhenius equation is a well-known chemical equation which relates reaction rate to temperature. Using this equation and the rate constants determined for $106^{o}C$ and $120^{o}C$, a rate constant was computed for $135^{o}C$. The value was 12.5. The associated predicted curve was then compared with Silverman's data at $135^{o}C$, and the result is shown in Figure 2.

A paper has been prepared applying the model of equation 1 and its use of N death mechanisms to nonlogarithmic microbial survival in a thermal environment. A report providing details of the model and its applications to spacecraft sterilization is in the typing phase. Simple computing methods for computing expected population when the temperature is variable are included with computed examples.

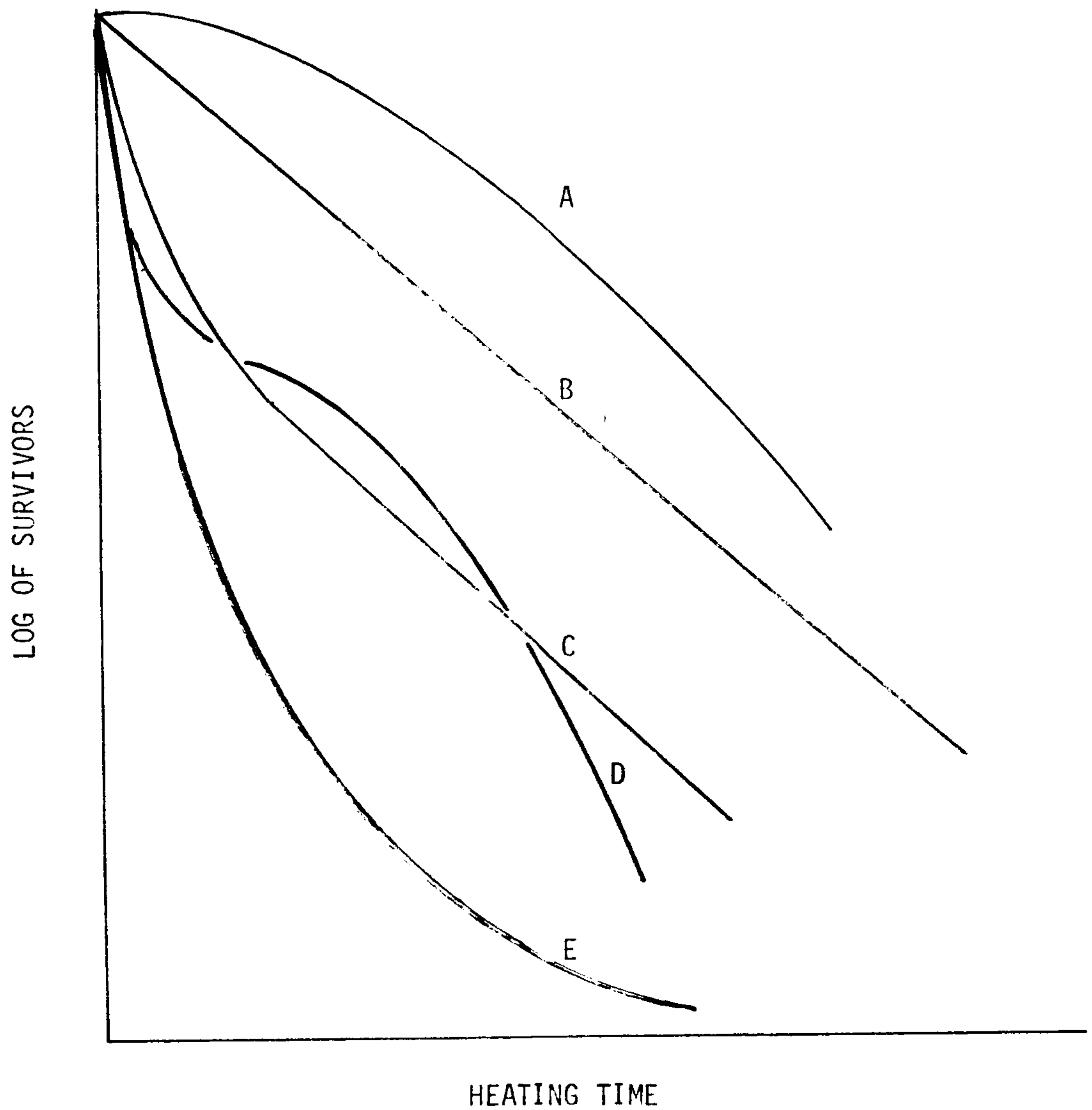

Figure 1.	INACTIVATION ORDER	N	n_1	n_2
CURVE A	1st	1	>1	—
CURVE B	1st	1	1	—
CURVE C	1st for 1st type 2nd for 2nd type	2	1	1
CURVE D	1st or 2nd	1	2	—
CURVE E	2nd	1	1	—

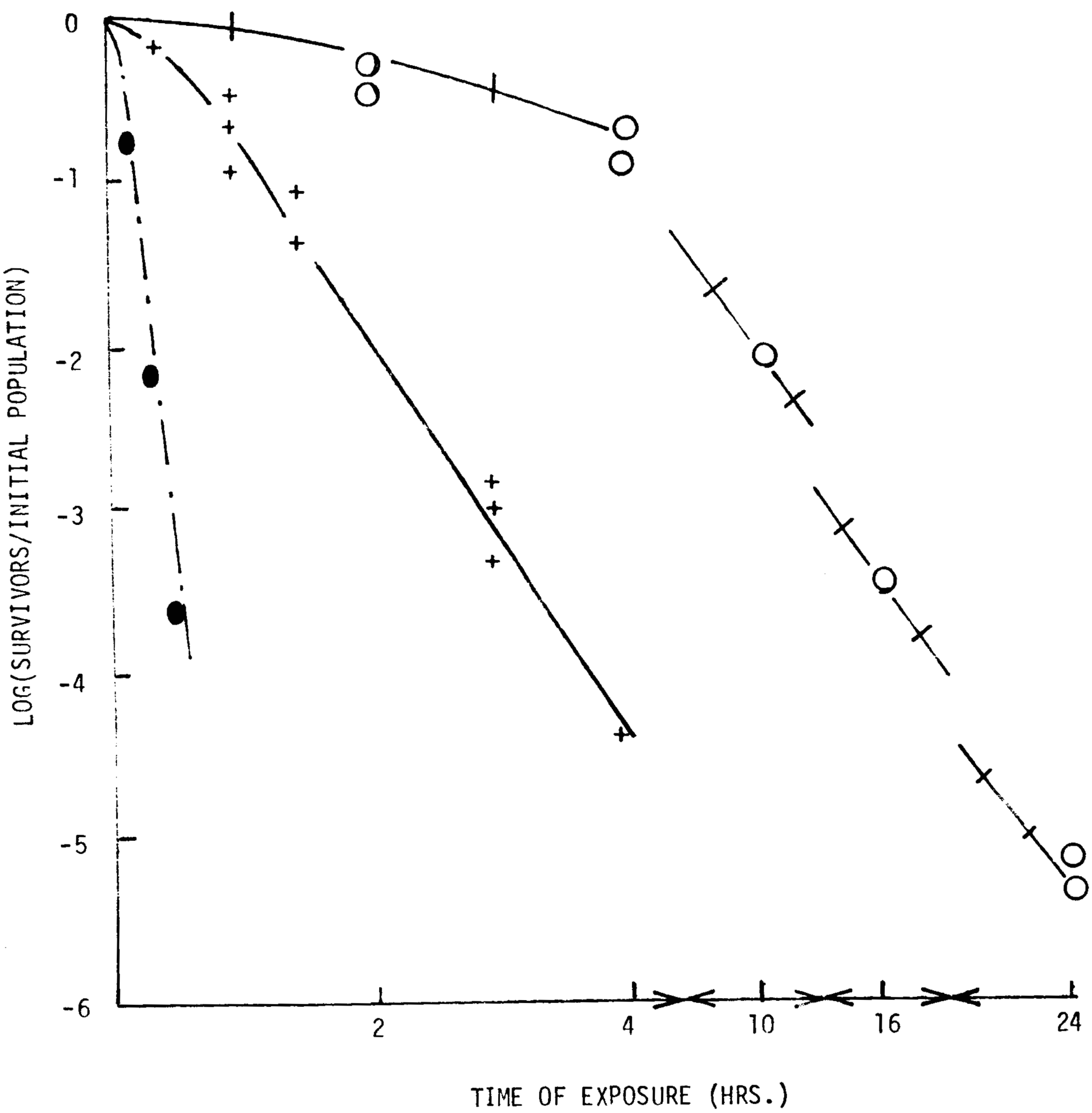

Figure 2: Silverman's Data

106^0C - 0

120^0C - +

135^0C - ●

$P(t) = 1-[1-\exp(-kt)]^2$

k = .55 $hr.^{-1}$ ┼┼ fit

k = 2.65 $hr.^{-1}$ —— fit

k = 12.5 $hr.^{-1}$ —·— predicted

II - SYSTEMS SUPPORT ACTIVITIES

(A) Planetary Quarantine System Support

The vacuum probe sampler unit which has been designated the "filter probe" is being optimized to reduce the percentage of microbial contamination which is lost by impingement on the walls of the filter housing. This optimization procedure has consisted of designing a housing which causes the smallest amount of air turbulence and of designing removable metal inserts which can be used as liners for the housing walls and can be overlaid with agar to provide microbial counts.

A report entitled "A New Approach to the Microbiological Sampling of Surfaces: The Vacuum Probe Sampler" (SC-RR-67-114) has been published. This report describes the principles of the new sampling technique, the protocol developed to test the device's performance, and the results of an extensive test program.

A study has been initiated to develop a physical model which is best suited for the collection and retention of viable microorganisms within a laminar airflow environment. The first segments of this study will involve studying airflow around different solid geometries within a laminar downflow study chamber. To provide a means of contaminating the different models with intramural microorganisms for testing, a laminar downflow unit without absolute filters is being obtained. This mechanism of contamination and the types of viable contaminants are similar to the true situations involved in laminar flow work environments.

Sampling studies to determine the microbial profile of hospital operating rooms have been completed. Isolation and identification of the contaminants from a nonlaminar airflow room are being completed. A report summarizing the results of this study will be issued during the next quarter.

Dry heat studies have been conducted in support of Spacecraft Sterilization Advisory Committee Subcommittee I activities. Results of these studies will be submitted and discussed during the Houston meeting of Subcommittee I in April 1967.

(B) Principles of Contamination Control

"Principles of Contamination Control"document is complete and will be delivered to NASA by April 1. The Office of Technical Utilization (UT) plans to publish this document as a NASA technical publication. Sandia also has the responsibility of reviewing the galley proofs before it is published.

This document contains basic principles of contamination control and is intended to supply guideline information for planning purposes. A model for contamination control was developed for this document which presents a more complete picture of the field than has been possible before. By use of the model, areas of contamination control are more closely and accurately related to each other.

In final form, the document should contain approximately 100 pages which includes approximately 50 illustrations.

(C) Contamination Control Study

Work performed on the contamination control study during the past quarter has consisted primarily of review of literature on cleaning agents and cleaning methods and of condensing and documenting some of that information as it applies to contamination control. Those sections of the final document which contain information on solvents, surfactants, acid cleaners, alkaline cleaners, and ultrasonic cleaning are being written.

Dr. T. J. Bulat, Manager of Sonic Energy Engineering, Bendix Corporation, Instruments & Life Support Division, visited Albuquerque to present an ultrasonic cleaning demonstration. Numerous technical aspects of ultrasonic cleaning were discussed with him in a personal conference at that time.

Plans for the joint NASA/AEC symposium on contamination control have progressed to fix the dates as September 12 through 14, 1967. The symposium will be held in Albuquerque, with arrangements being made by Sandia Laboratory. A tentative list of papers which are to be considered for invitation has been prepared and mailed to paper committee members for review.

At a meeting at Cape Kennedy on March 1, 1967, committees were formed, and chairmen and some committee members were named. The symposium chairmen and committees are:

General Chairman:		H. D. Sivinski, Sandia
Vice Chairman:		F. J. Beyerle, MSFC
Arrangements Committee Chairman:		J. R. Sublett, Sandia
Papers Committee:		
	Chairman:	W. L. Clement, Sandia
	Members:	W. J. Whitfield, Sandia L. J. Klamerus, Sandia Q. T. Ussery, MSC Dr. John Gayle, KSC F. J. Beyerle, MSFC

III - MISCELLANEOUS

(A) Publications

1. V. L. Dugan, W. J. Whitfield, J. J. McDade, J. W. Beakley, F. W. Oswalt, "A New Approach to the Microbiological Sampling of Surfaces: The Vacuum Probe Sampler", SC-RR-67-114, March 1967.

(B) Subcommittee II Meeting

The first meeting of the Subcommittee on Mathematical Models of the Spacecraft Sterilization Advisory Committee coordinated by the American Institute of Biological Sciences was held in Tallahassee, Florida, on February 8 and 9.

The objectives of this meeting were to:

1. Outline a mutually agreeable approach to the development of the Planetary Quarantine program and
2. Discuss the objectives, assumptions and considerations occurring in specific models used in the Planetary Quarantine program with a view toward arriving at a mutually agreeable set of each.

A. L. Wyer, 2571, presented a talk entitled, "An Approach to Program Development and Analysis", in which he outlined an approach to these items which is dependent upon program objectives and an analysis of them. (See Section I.A.2)

E. J. Sherry, 2571, discussed the recently developed model explained in Section I.B. He emphasized the need to consider other National objectives (for example, experimental success) when attempting to analyze National Planetary Quarantine objectives.

J. P. Brannen, 2571, described the microbial death model treated in Section I.C. This model is based upon the assumption that thermal death of microorganisms is due to chemical inactivations of "vital" types of molecular structures in the cell.

Distribution:
J. A. Hornbeck, 1
C. F. Bild, 1100
W. J. Howard, 1000
R. W. Henderson, 2000
L. J. Heilman, 2100
T. T. Robertson, 2200
L. J. Paddison, 2400
H. E. Lenander, 2500
J. R. Meikle, 2520
J. W. Jones, 2540
R. E. Hepplewhite, 2550
J. R. Sublett, 2560
D. W. Ballard, 2564
H. D. Sivinski, 2570 (20)
R. C. Fletcher, 5000
R. S. Claassen, 5100
T. B. Cook, Jr., 5200
J. W. Weihe, 5250
D. P. Peterson, 5253
M. J. Norris, 5260
J. M. Worrell, Jr., 5261
L. D. Smith, 5500
B. H. VanDomelen, 5530
M. C. Reynolds, 5530
R. T. Dillon, 5590
J. H. Scott, 9200
A. Y. Pope, 9300
J. W. McKiernan, 9331
W. F. Carstens, 3410
L. C. Baldwin, 3412
R. S. Gillespie, 3413 (4)
C. H. Sproul, 3415-3
B. R. Allen, 3421
M. G. Randle, 3428-1, Bldg. 802
B. F. Hefley, 8232

NASA, Code SC
Grants and Contracts
400 Maryland Avenue, S.W.
Washington, D. C. 20546 (25)

L. B. Hall, NASA
Code SB
400 Maryland Avenue, SW
Washington, D. C. 20546 (25)

W. E. Clapper
Lovelace Foundation
5200 Gibson Blvd.SE
Albuquerque, New Mexico

J. J. McDade
Lovelace Foundation
5200 Gibson Blvd. SE
Albuquerque, New Mexico

University of California, LRL
P. O. Box 808
Livermore, California 94551
Attn: Tech. Info. Div.
For: Report Librarian

Los Alamos Scientific Laboratory
P. O. Box 1663
Los Alamos, New Mexico
Attn: Report Librarian

Carol Franklin
Lovelace Foundation
5200 Gibson Blvd.
Albuquerque, New Mexico

Gerald Silverman
Department of Nutrition and Food Science
Massachusetts Institute of Technology
Cambridge, Massachusetts 02139

Richard G. Bond
School of Public Health
College of Medical Science
University of Minnesota
Minneapolis, Minnesota 55455

John H. Brewer
Biological Safety and Control
Becton, Dickinson and Company
P. O. Box 6711
Baltimore, Maryland 21204

Mark A. Chatigny
Research Engineer
Naval Biological Laboratory
Naval Supply Center
University of California, Berkeley
Oakland, California 94625

Richard G. Cornell
Associate Professor of Statistics
Department of Statistics
Florida State University
Tallahassee, Florida

Frank B. Engley, Jr.
Chairman, Department of Microbiology
School of Medicine
University of Missouri
Columbia, Missouri

Gilbert V. Levin
Hazleton Laboratories, Inc.
Box 30
Falls Church, Virginia

Irving J. Pflug
Department of Food Science
Michigan State University
East Lansing, Michigan

John A. Ulrich
Department of Microbiology
Mayo Clinic
Rochester, Minnesota 55902

Samuel Schalkowsky
Exotech Incorporated
525 School Street, S.W.
Washington, D. C. 20024

Charles Craven
Jet Propulsion Laboratory
4800 Oak Grove Dr.
Pasadena, California 91103

Martin S. Favero
Department of Health, Ed. and Welfare
CDC-Phoenix Field Station
4402 North 7th Street
Phoenix, Arizona 85014

F. N. LeDoux
Head, Structural & Mechanical
Applications Section
Goddard Space Flight Center
Greenbelt, Maryland

Q. Ussery
Code AR5, Quality Assurance Branch
Manned Spacecraft Center, NASA
Houston, Texas

F. J. Beyerle
George C. Marshall Space Flight Center
Manufacturing Engineering Laboratory
M/F Building 4471
Huntsville, Alabama 35812

J. Gayle
Code SOP
Kennedy Space Center, NASA
Cape Kennedy, Florida

E. Rich
Code 624
GSFC Sterilization Laboratory
Goddard Space Flight Center
Greenbelt, Maryland 20771

N. H. MacLeod
Space Biology Branch
Code 624, Bldg. 21, Rm. 161
Goddard Space Flight Center
Greenbelt, Maryland 20771

Robert Angelotti
Deputy Chief, Milk and Food Res.
Robert A. Taft Sanitary Engineering Center
Cincinatti, Ohio

H. G. Lorsch, Manager
Spacecraft Sterilization
Valley Forge Space Technology Center
General Electric Company
P. O. Box 8555
Philadelphia, Pennsylvania 19101

Carl Bruch
Chief, Bacteriology Branch
Division of Microbiology
Food and Drug Administration
3rd & C., SW, Room 3876
Washington, D. C. 20204

John W. Beakley
Department of Biology
University of New Mexico
Albuquerque, New Mexico

Loren D. Potter, Chairman
Department of Biology
University of New Mexico
Albuquerque, New Mexico

Joe Stern
Jet Propulsion Laboratory
4800 Oak Grove Dr.
Pasadena, California 91103